Nutritive value and display-life attributes of selenium-enriched beef-muscle foods

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Abstract

Our objective was to assess the nutritive value and display-life attributes of selenium-enriched beef-muscle foods. Samples of foreshank and short-loin subprimals were excised from chilled carcasses (n = 20) of beef steers that were individually finished (120 days) on either supranutritional selenium (selenium-enriched; 68.1 μg Se/kg body weight/day; n = 9) or adequate selenium (non-enriched; 9.1 μg Se/kg body weight/day; n = 11) diets. High-selenium wheat grain was included in the diet of supranutritional selenium-fed steers to achieve selenium-enrichment. Selenium-enriched foreshank had 3.8 times more (1085 vs. 283 ng/g wet weight, P < 0.01) selenium and 1.3 times more (P < 0.01) glutathione peroxidase activity than non-enriched foreshank samples. Selenium-enrichment did not influence foreshank (P = 0.16–0.89) moisture, ash, crude protein, and lipid contents, and expressible moisture, or short-loin (P = 0.11–0.41) drip-loss percentage or color change throughout the display-life evaluation. The results indicate that, compared to non-enriched, selenium-enriched beef-muscle foods have a much higher amount of selenium and similar display-life attributes.

Keywords: Selenium; Beef; Enrichment; Display-life; Muscle foods; Selenomethionine; SeMet

1. Introduction

Increased selenium (Se) intakes have been associated with reduced risks of certain cancers in humans (for review, see Combs, 2005). Accordingly, scientists have investigated several foods (e.g., vegetables, cereal grains, and muscle foods) that are naturally high in Se or can be readily enriched with the element (Ip and Lisk, 1993; Finley, 1999; Whanger et al., 2000; Taylor, 2005). Selenium-enrichment of ruminant muscle foods can occur when Se is included in the animal’s diet as selenomethionine (SeMet), particularly at greater than required levels (Hintze et al., 2002; Lawler et al., 2004; Taylor, 2005). This is due to the incorporation of SeMet in lieu of methionine in protein synthesis. Selenomethionine is a dominant form of Se in plants (for review, see Whanger, 2002). Unlike manufactured supplemental sources of Se, such as Se-enriched yeasts, inclusion of naturally high-Se feedstuffs in livestock diets is not regulated in the United States (FDA, 2006). Recently, we reported a 3.5-fold increase in the Se content of skeletal muscle from beef steers finished on a supranutritional-Se diet formulated with high-Se wheat grain and alfalfa-grass hay, compared with those finished on Se-adequate diets (Lawler et al., 2004). These supranutritional-Se diets did not negatively influence steer performance or carcass characteristics. Although some studies have documented the effects of inorganic-Se compounds on carcass/meat attributes and traits (Mahan et al., 1999; Payne and Southern, 2005), none have been conducted to determine the influence of a naturally high source of SeMet on beef quality. Therefore, the objective of the present study was to...
2. Materials and methods

Muscle-food samples of subprimal cuts (subprimals) were obtained from 20 chilled (48 h) carcasses (339 ± 7 kg) that originated from a study of the effects of supranutritional Se on performance and carcass characteristics of finishing beef steers; performance and carcass measures have been reported (Lawler et al., 2004; Soto-Navarro et al., 2004). Briefly, steers (initial body weight = 351 ± 24 kg) were individually fed (120 days) either 68.1 μg Se/kg body weight/day (n = 9; supranutritional Se) or 9.1 μg Se/kg body weight/day (n = 11; adequate Se). High-Se wheat (10.3 mg Se/kg dry matter; harvested from a seleniferous region near Pierre, SD) directly replaced normal-Se wheat (0.40 mg Se/kg dry matter; harvested near Georgetown, MN) to deliver supranutritional Se. Diets were similar in feed (25% wheat, 39% corn, 25% grass hay, 5% condensed separator byproduct, and 6% wheat middling based supplement) and nutrient (14.0% crude protein, 2.12 Mcal NEm/kg, and 1.26 Mcal NEm/kg; NRC, 1996) compositions (all values expressed on a dry matter basis).

In order to facilitate ease of sampling and minimize damage to greater-value subprimals, samples were taken from the foreshank (ulnaris lateralis; IMPS #117, USDA, 1996) for end-point nutrient/attribute and glutathione peroxidase activity (GSH-Px) analyses. For display-life evaluation, samples were taken from the short loin (M. longissimus; IMPS #173, USDA, 1996). Immediately following slaughter, carcasses were chilled (4°C) for 48 h. Foreshank samples (~3 g wet basis) were collected at 0, 6, 12, 24, 36 and 48 h, wrapped in foil, frozen in liquid nitrogen, and stored (~80°C). Moisture, ash, crude protein, lipids (AOAC, 1990), expressible moisture (Jauréguí et al., 1981), and Se (hydride generation atomic absorption spectrometry; Finley et al., 1996) were measured in 0-h samples. Glutathione peroxidase activity was measured in 0, 6, 12, 24, 36 and 48 h samples using the enzyme-coupled procedure of Paglia and Valentine (1967). Selenium concentration was 3.8 times more (P < 0.01) in Se-enriched than in non-enriched foreshank samples. Moisture, ash, crude protein, and lipid content were similar (P = 0.16–0.89) between Se- and non-enriched foreshank samples. Regardless of chilling time (Se-enrichment × chilling-time effect, P = 0.88), GSH-Px activity was greater (P < 0.01) in Se-enriched foreshank samples. Short-loin-sample drip loss and Hunter L, a, and b value least squares means are presented in Table 2. Neither Se-enrichment × display-time (P = 0.55–0.99) nor Se-enrichment (P = 0.07–0.93) influenced drip loss or Hunter L, a, or b values.

3. Results

Foreshank-sample nutrients, expressible-moisture, and GSH-Px measurement least squares means are presented in Table 1. Selenium concentration was 3.8 times more (P < 0.01) in Se-enriched than in non-enriched foreshank samples. Moisture, ash, crude protein, and lipid content were similar (P = 0.16–0.89) between Se- and non-enriched foreshank samples. Regardless of chilling time (Se-enrichment × chilling-time effect, P = 0.88), GSH-Px activity was greater (P < 0.01) in Se-enriched foreshank samples. Short-loin-sample drip loss and Hunter L, a, and b value least squares means are presented in Table 2. Neither Se-enrichment × display-time (P = 0.55–0.99) nor Se-enrichment (P = 0.07–0.93) influenced drip loss or Hunter L, a, or b values.

Table 1

<table>
<thead>
<tr>
<th>Item</th>
<th>Se-enriched</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Selenium (ng/g)</td>
<td>283 ± 29</td>
<td>1085 ± 3</td>
</tr>
<tr>
<td>GPX activity</td>
<td>264 ± 14</td>
<td>345 ± 14</td>
</tr>
<tr>
<td>Moisture (%)</td>
<td>71.5 ± 0.4</td>
<td>71.4 ± 0.4</td>
</tr>
<tr>
<td>Ash (%)</td>
<td>1.08 ± 0.01</td>
<td>1.07 ± 0.01</td>
</tr>
<tr>
<td>Crude protein (%)</td>
<td>23.2 ± 0.2</td>
<td>22.8 ± 0.2</td>
</tr>
<tr>
<td>Lipid (%)</td>
<td>5.07 ± 0.42</td>
<td>5.38 ± 0.46</td>
</tr>
<tr>
<td>Expressible moisture</td>
<td>39.3 ± 1.3</td>
<td>40.0 ± 1.5</td>
</tr>
</tbody>
</table>

*Samples were excised from chilled carcasses (n = 20) of beef steers individually fed (120 days) either 9.1 μg Se/kg body weight/day (n = 11; no: non-enriched) or 68.1 μg Se/kg body weight/day (n = 9; yes: Se-enriched).

aF-test probability.

Repeated samples were collected at 0, 6, 12, 24, 36, and 48 h during the chilling period. Data were analyzed as repeated measures. No time x treatment interactions were detected; as such, the main effect least squares means are reported.

Expressed as a percentage of initial sample weight.
4. Discussion

Selenium-enrichment of foreshank muscle was at least 3.8 times more in steers fed supranutritional Se from high-Se wheat grain compared to steers fed a Se-adequate diet. This enrichment did not alter the major-nutrient (other than Se) content of foreshank or display-life attributes of short loin. The magnitude of Se-enrichment of beef-skeletal muscle seems homogeneous across various retail cuts (Hintze et al., 2002). Therefore, we expect similar responses to Se-enrichment throughout all subprimal cuts, as observed in the short loin and foreshank.

That the muscle-GSH-Px activity detected in Se-enriched foreshank was greater than that in non-enriched foreshank was unexpected. Up-regulation of GSH-Px synthesis in response to increased dietary Se is expected in individuals that are deficient or, at most, marginal with respect to the element (Waschulewski and Sunde, 1988; Behne and Kyriakopoulos, 1993; Berggren et al., 1999), but not in Se-adequate animals. In the present case, the Se-adequate diets, which were formulated with “normal-Se” feedstuffs, contained approximately 126% (0.38 mg Se/kg dry matter; Lawler et al., 2004) of the recommended amount of Se for finishing steers (NRC, 1996), suggesting that they should have expressed maximal levels of muscle GSH-Px. That treatment differences were, in fact, detected suggests either that inter-individual differences in foreshank GSH-Px activity (not assessed before the initiation of dietary treatments) were greater than anticipated, or that the “Se-adequate” diet actually did not support maximal GSH-Px expression, at least in the foreshank. This view is consistent with the finding that the magnitude of Se-enrichment (3.8-fold) was much greater than the apparent GSH-Px difference between Se-enriched and non-enriched foreshank samples. Likewise, whole blood GSH-Px activity increased in “Se-adequate” beef steers fed supranutritional-Se diets (Hintze et al., 2002).

In the present study, Se-enrichment did not affect display-life attributes of muscles that were evaluated. Supplemening diets with Se-enriched yeast, at or near the respective Se requirement, reduced drip loss in broilers (Choct et al., 2004) and tended to have the same affect in pigs (Mahan et al., 1999), with beneficial effects achieved when Se was fed at or near required levels. Such effects were not observed in the present study.

Selenium-enrichment of skeletal muscle seems predictable and may be managed to produce targeted, possibly consumer defined, concentrations of Se in typical retail muscle foods (Taylor, 2005). Regardless of livestock species, Se-enrichment of muscle foods can be achieved when feeding SeMet in an amount sufficient for it to compete favorably with methionine for the synthesis of muscle proteins accreted during growth (McConnell and Hoffman, 1972; Waschulewski and Sunde, 1988; Butler et al., 1989). This process becomes more efficient when the dietary requirement for Se has largely been met (Hintze et al., 2002; Lawler et al., 2004; Taylor, 2005).

A 100-g serving of the muscle foods examined in this study would provide approximately 109 µg of dietary Se, which is two-fold the current Dietary Reference Intake (DRI, 2000) for adult humans (55 µg/day). Consumption of this product in place of a 100-g serving of muscle foods originating from food-animals fed Se-adequate diets would result in an approximate net increased Se intake of 75 µg. For Americans, such a net increase would not only meet the RDA, but would also provide the level of Se, estimated by Combs (2005) to be ~100 µg/day, associated with cancer risk reduction in the Nutritional Prevention of Cancer trial (Clark et al., 1996). It is important to note that this notion (Combs, 2005) was presented in the context of Se-supplementation in the form of SeMet.

5. Conclusions

Muscle foods,— from beef steers fed supranutritional-Se diets, formulated with high-Se wheat grain, had 3.8 times more Se content than similar products from beef steers fed Se-adequate diets. Compared to non-enriched, selenium-enriched beef-muscle foods have a much higher amount of selenium, and similar display-life attributes and major-nutrient contents. Targeted (i.e., custom) enrichment of muscle foods with Se is a viable and safe process for generating naturally enriched, higher-Se foods for human consumption.

Acknowledgment

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